OPERATING SYSTEMS

Lesson 3: PROCESSES

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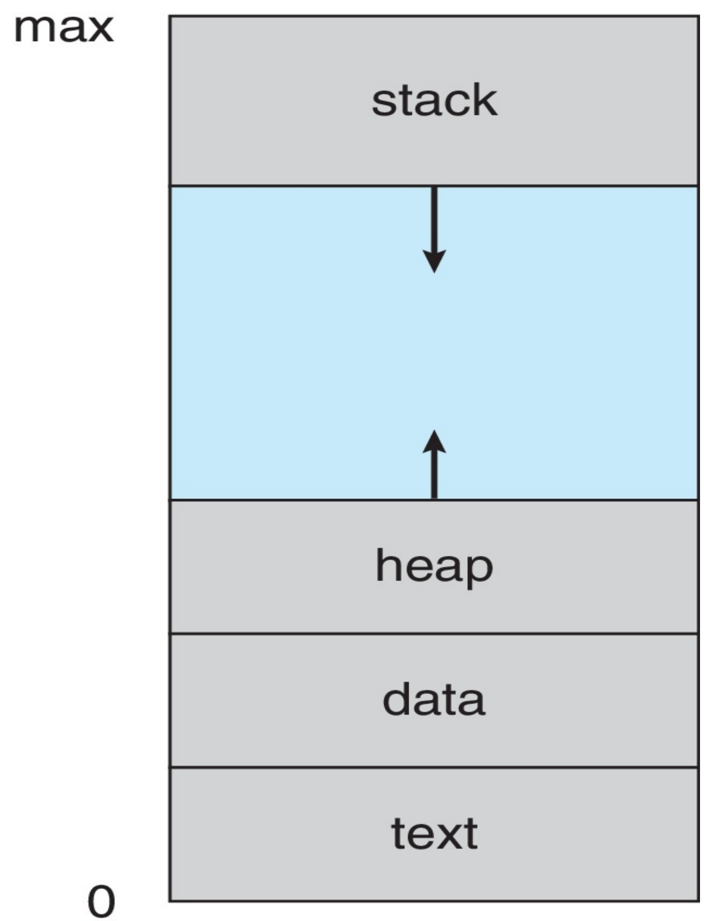
CONTENTS

Process Concept

- An operating system executes a variety of programs that run as a process.
- **Process** – a program in execution; process execution must progress in sequential fashion
- Multiple parts
  - The program code, also called **text section**
  - Current activity including **program counter**, processor registers
  - **Stack** containing temporary data
    - Function parameters, return addresses, local variables
  - **Data section** containing global variables
  - **Heap** containing memory dynamically allocated during run time

Process in Memory



Memory Layout of a C Program

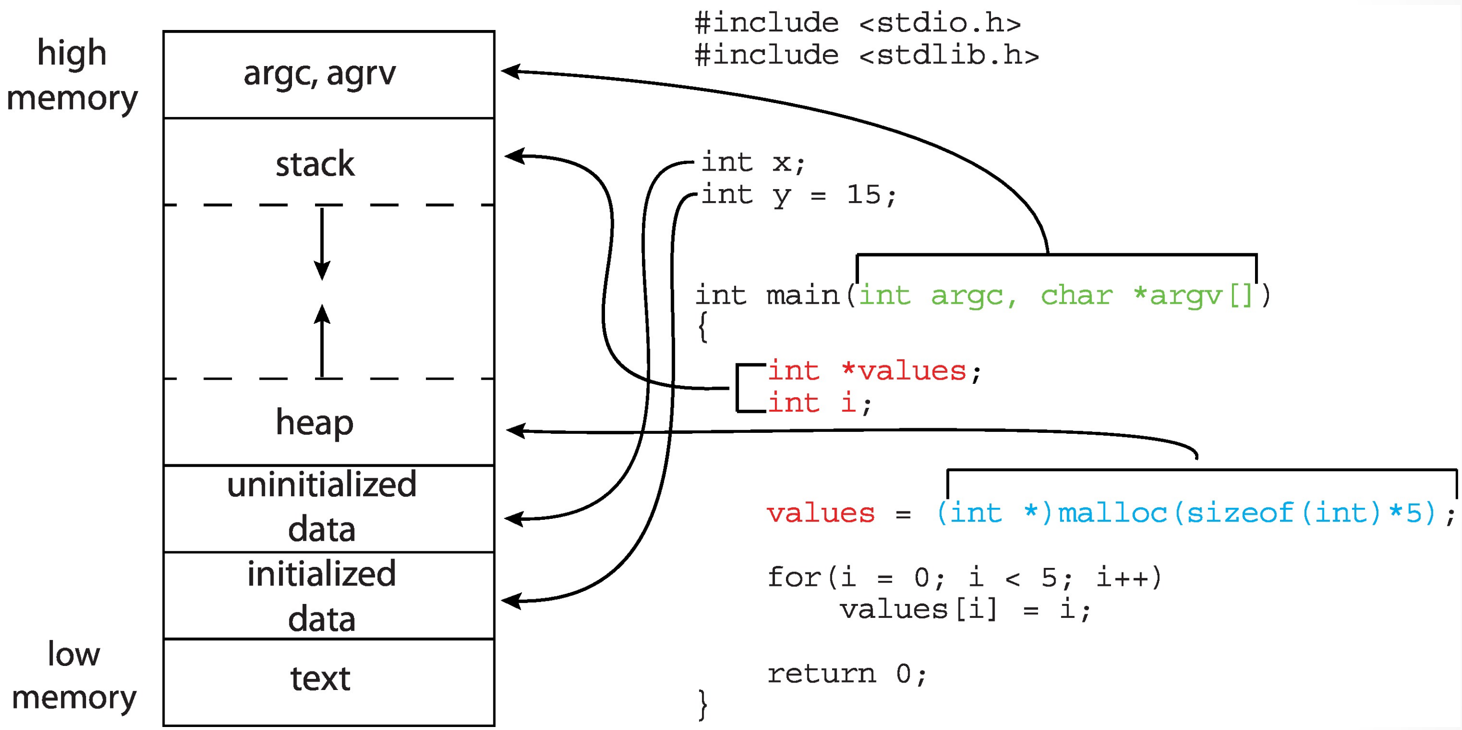
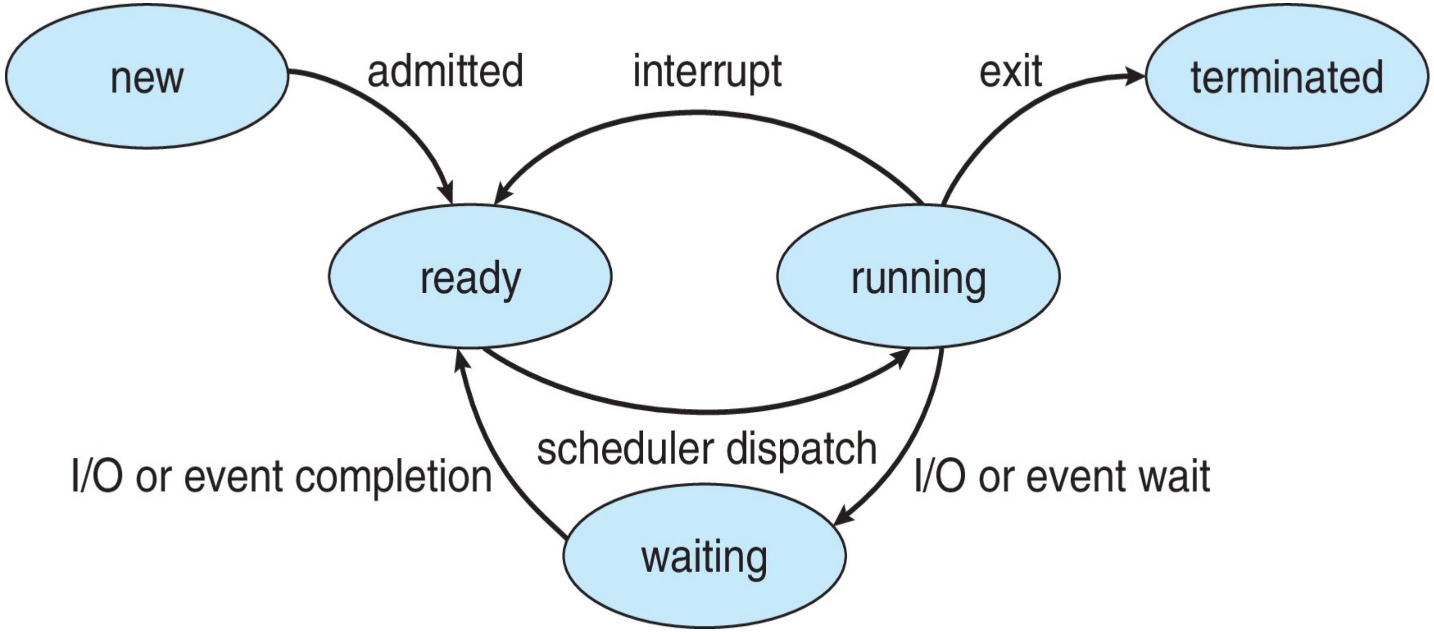


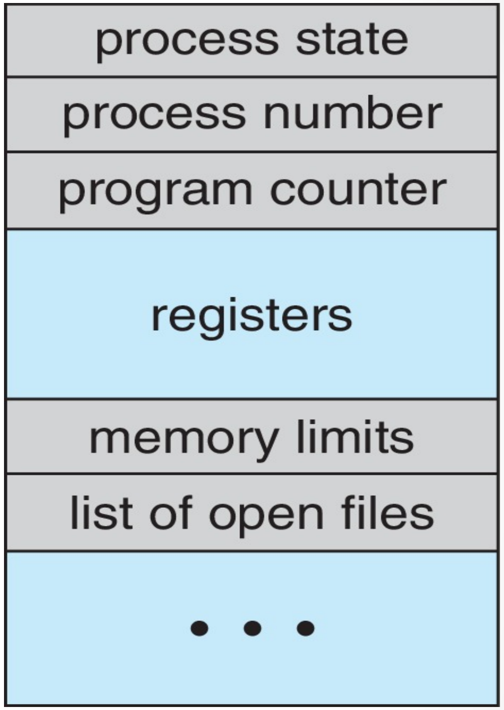
Diagram of Process State



Process Control Block (PCB)

Information associated with each process (also called **task control block**)

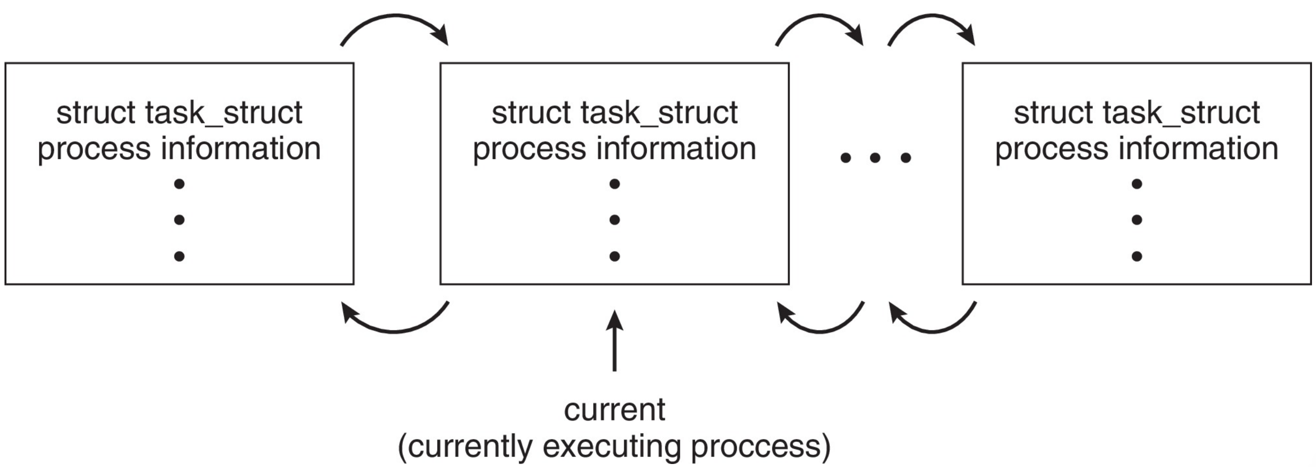
- Process state – running, waiting, etc
- Program counter – location of instruction to next execute
- CPU registers – contents of all process-centric registers
- CPU scheduling information- priorities, scheduling queue pointers
- Memory-management information – memory allocated to the process
- Accounting information – CPU used, clock time elapsed since start, time limits
- I/O status information – I/O devices allocated to process, list of open files



Process Representation in Linux

Represented by the C structure `task_struct`

```
pid t_pid;                    /* process identifier */
long state;                   /* state of the process */
unsigned int time_slice       /* scheduling information */
struct task_struct *parent;/* this process's parent */
struct list_head children; /* this process's children */
struct files_struct *files;/* list of open files */
struct mm_struct *mm;         /* address space of this
process */
```

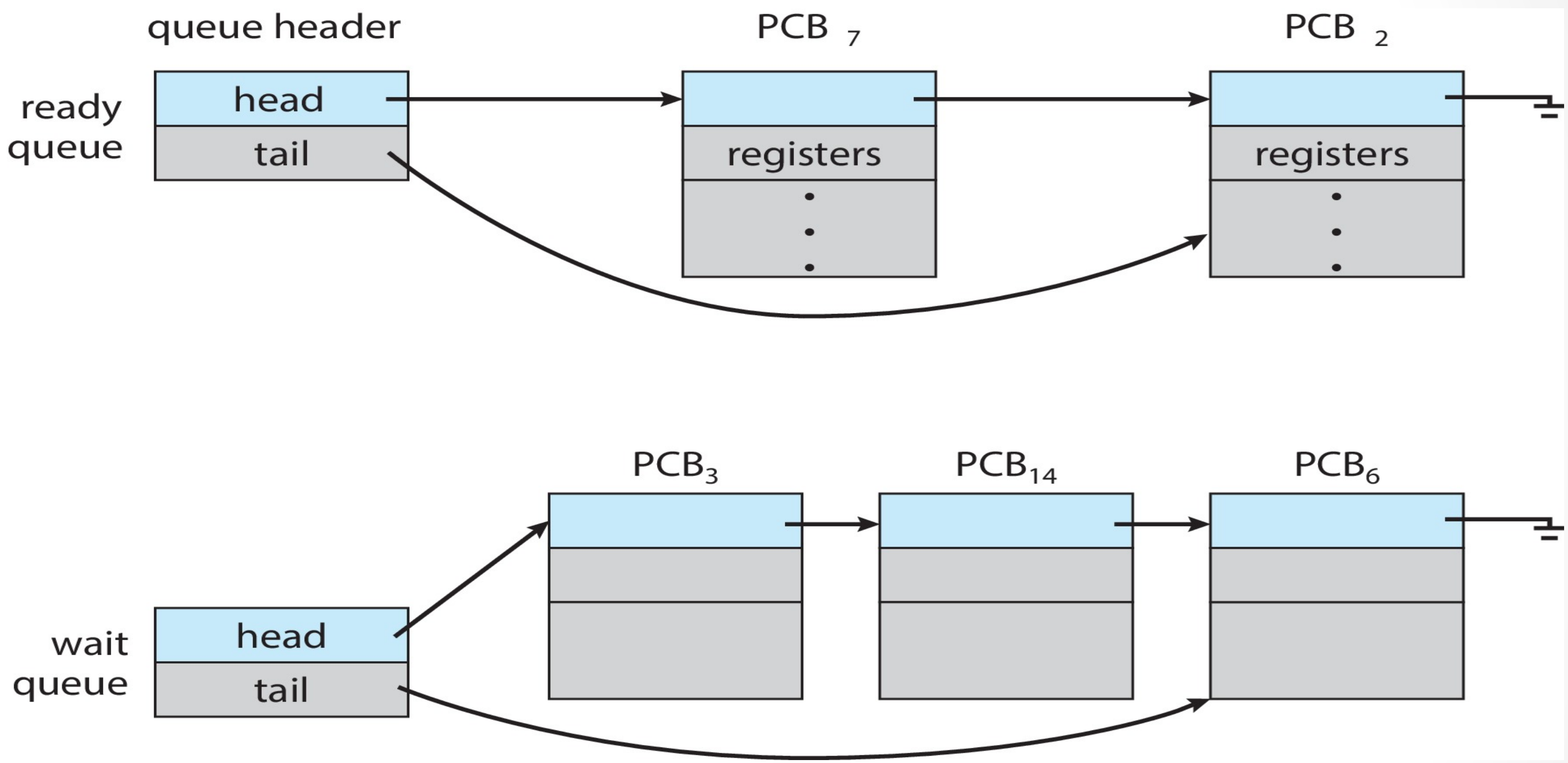


PROCESS SCHEDULING

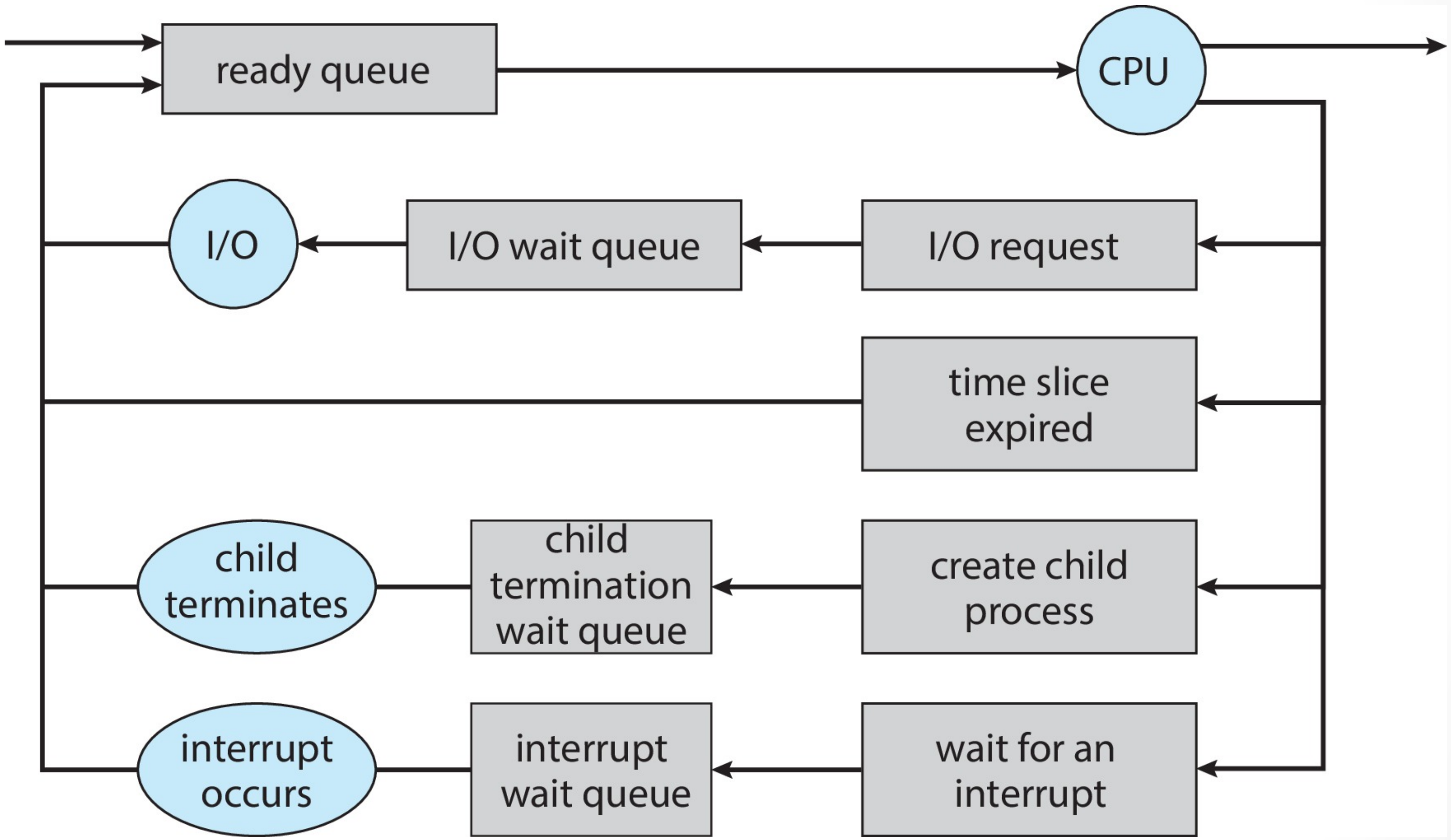
Process Scheduling

- Maximize CPU use, quickly switch processes onto CPU core
- **Process scheduler** selects among available processes for next execution on CPU core
- Maintains **scheduling queues** of processes
  - **Ready queue** – set of all processes residing in main memory, ready and waiting to execute
  - **Wait queues** – set of processes waiting for an event (i.e. I/O)
  - Processes migrate among the various queues

Ready and Wait Queues

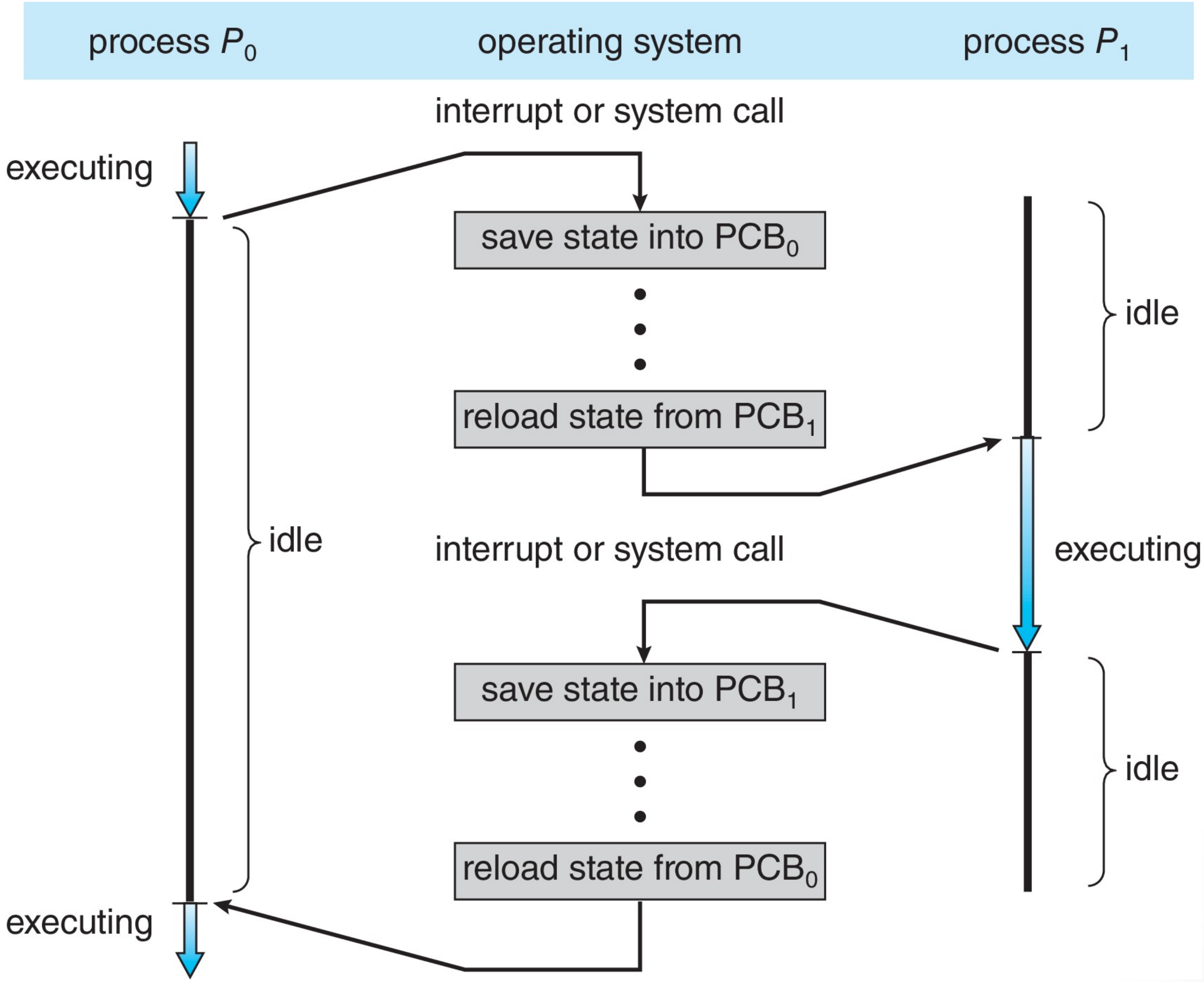


Representation of Process Scheduling



CPU Switch From Process to Process

A **context switch** occurs when the CPU switches from one process to another.



Context Switch

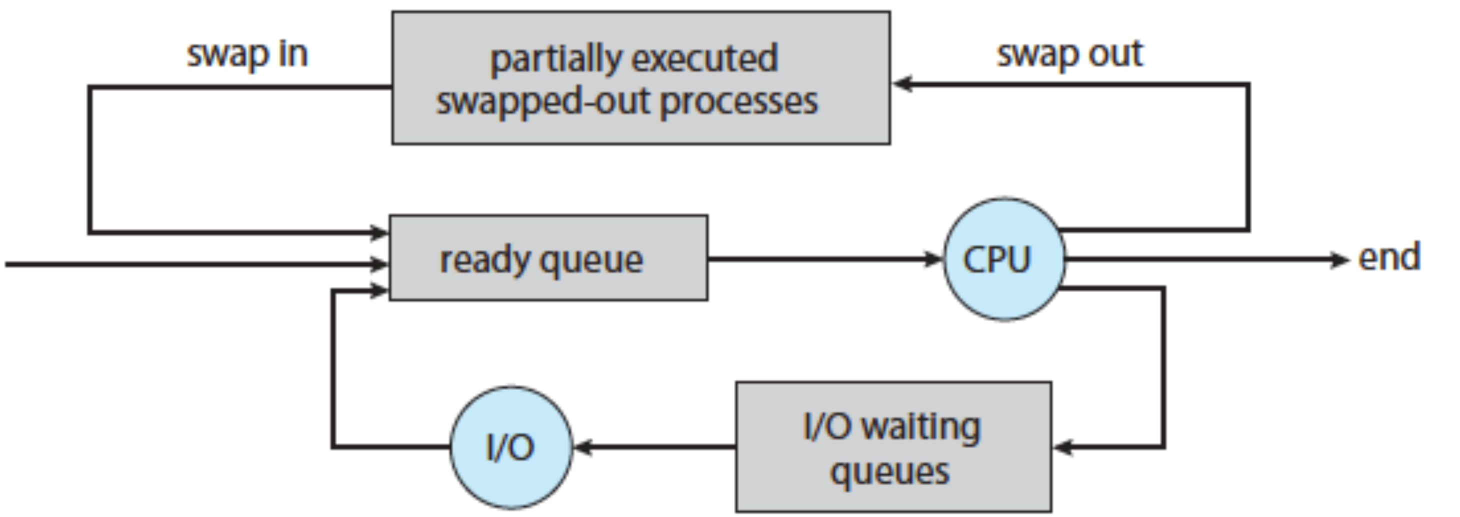
- When CPU switches to another process, the system must **save the state** of the old process and load the **saved state** for the new process via a **context switch**
- **Context** of a process represented in the PCB
- Context-switch time is overhead; the system does no useful work while switching
  - The more complex the OS and the PCB ➔ the longer the context switch
- Time dependent on hardware support
  - Some hardware provides multiple sets of registers per CPU ➔ multiple contexts loaded at once

SCHEDULERS

The selection process is carried out by the appropriate scheduler:

- The long-term scheduler, or job scheduler, selects processes from this pool and loads them into memory for execution.
- The short-term scheduler, or CPU scheduler, selects from among the processes that are ready to execute and allocates the CPU to one of them.
- The medium-term scheduler selects a process to remove from memory (and from active contention for the CPU) and also select a process to be reintroduced into memory, and its execution can be continued where it left off

A medium-term scheduler



OPERATIONS ON PROCESSES

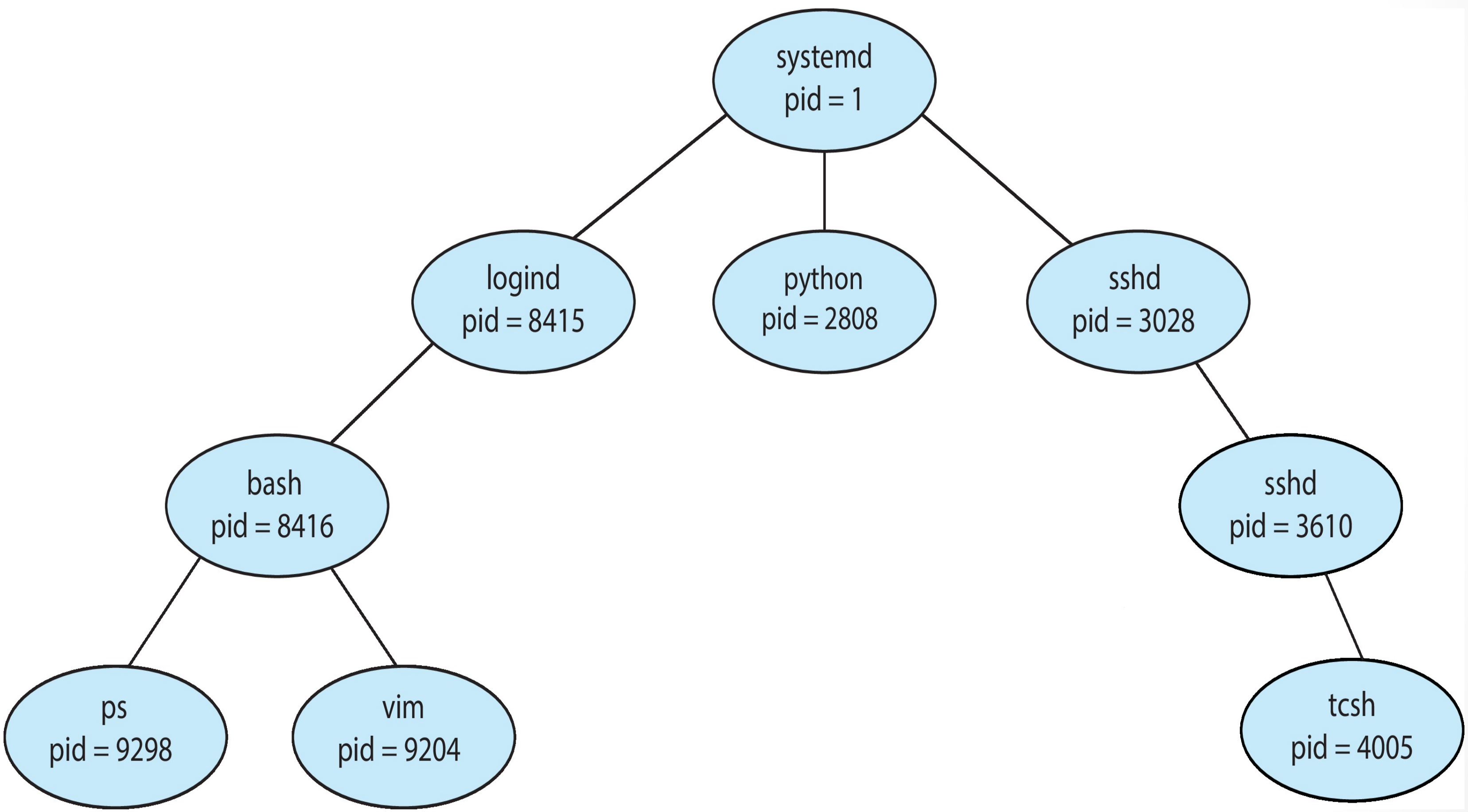
Process creation

Process termination

Process Creation

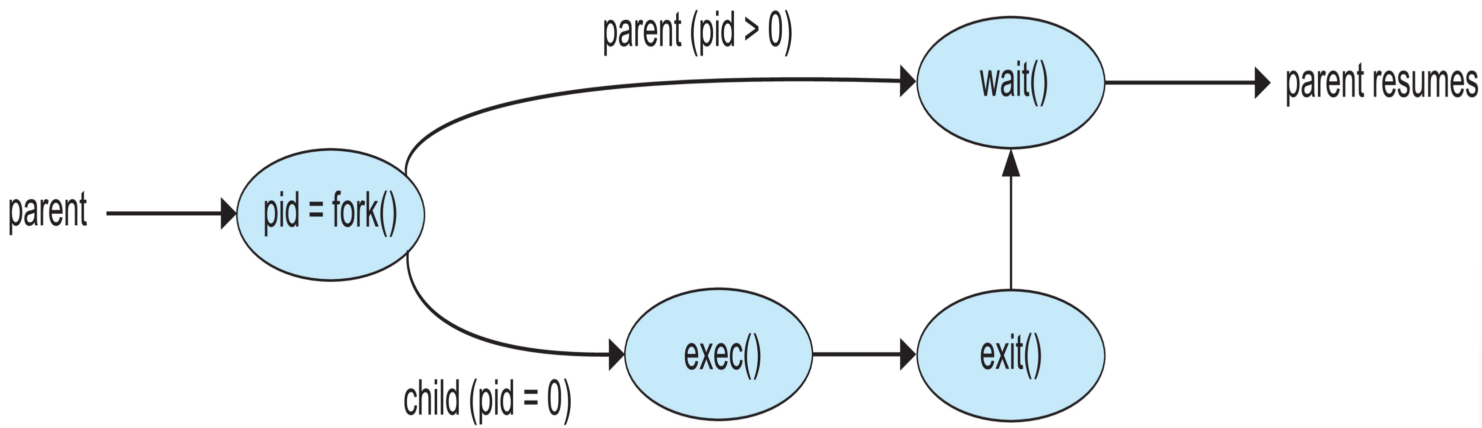
- **Parent** process create **children** processes, which, in turn create other processes, forming a **tree** of processes
- Generally, process identified and managed via a **process identifier** (**pid**)
- Resource sharing options
  - Parent and children share all resources
  - Children share subset of parent's resources
  - Parent and child share no resources
- Execution options
  - Parent and children execute concurrently
  - Parent waits until children terminate

A Tree of Processes in Linux



Process Creation (Cont.)

- Address space
  - Child duplicate of parent
  - Child has a program loaded into it
- UNIX examples
  - `fork()` system call creates new process
  - `exec()` system call used after a `fork()` to replace the process' memory space with a new program
  - Parent process calls `wait()` for the child to terminate



C Program Forking Separate Process

```
#include <sys/types.h>
#include <sys/wait.h>
#include <stdio.h>
#include <unistd.h>

int value = 5;

int main(){

printf("\n Before fork()”);
pid_t pid;
pid = fork();
if (pid < 0) { /* error occurred */
fprintf(stderr, "\n Fork Failed”);
return 1;
      }
else if (pid == 0) { /* child process */
value += 15;
printf("\n CHILD: value = %d",value);
/* LINE A */
return 0;
      }
else if (pid > 0) { /* parent process */
wait(NULL);
printf("\n PARENT: value = %d",value);
/* LINE B */
return 0;
      }
}
```

Process Termination

- Process executes last statement and then asks the operating system to delete it using the `exit()` system call.
  - Returns status data from child to parent (via `wait()`)
  - Process' resources are deallocated by operating system
- Parent may terminate the execution of children processes using the `abort()` system call. Some reasons for doing so:
  - Child has exceeded allocated resources
  - Task assigned to child is no longer required
  - The parent is exiting and the operating systems does not allow a child to continue if its parent terminates

Process Termination

- Some operating systems do not allow child to exists if its parent has terminated. If a process terminates, then all its children must also be terminated.
  - **cascading termination.** All children, grandchildren, etc. are terminated.
  - The termination is initiated by the operating system.
- The parent process may wait for termination of a child process by using the **`wait()`** system call. The call returns status information and the pid of the terminated process

```
pid = wait(&status);
```

- If no parent waiting (did not invoke **`wait()`**) process is a **zombie**
- If parent terminated without invoking **`wait`**, process is an **orphan**

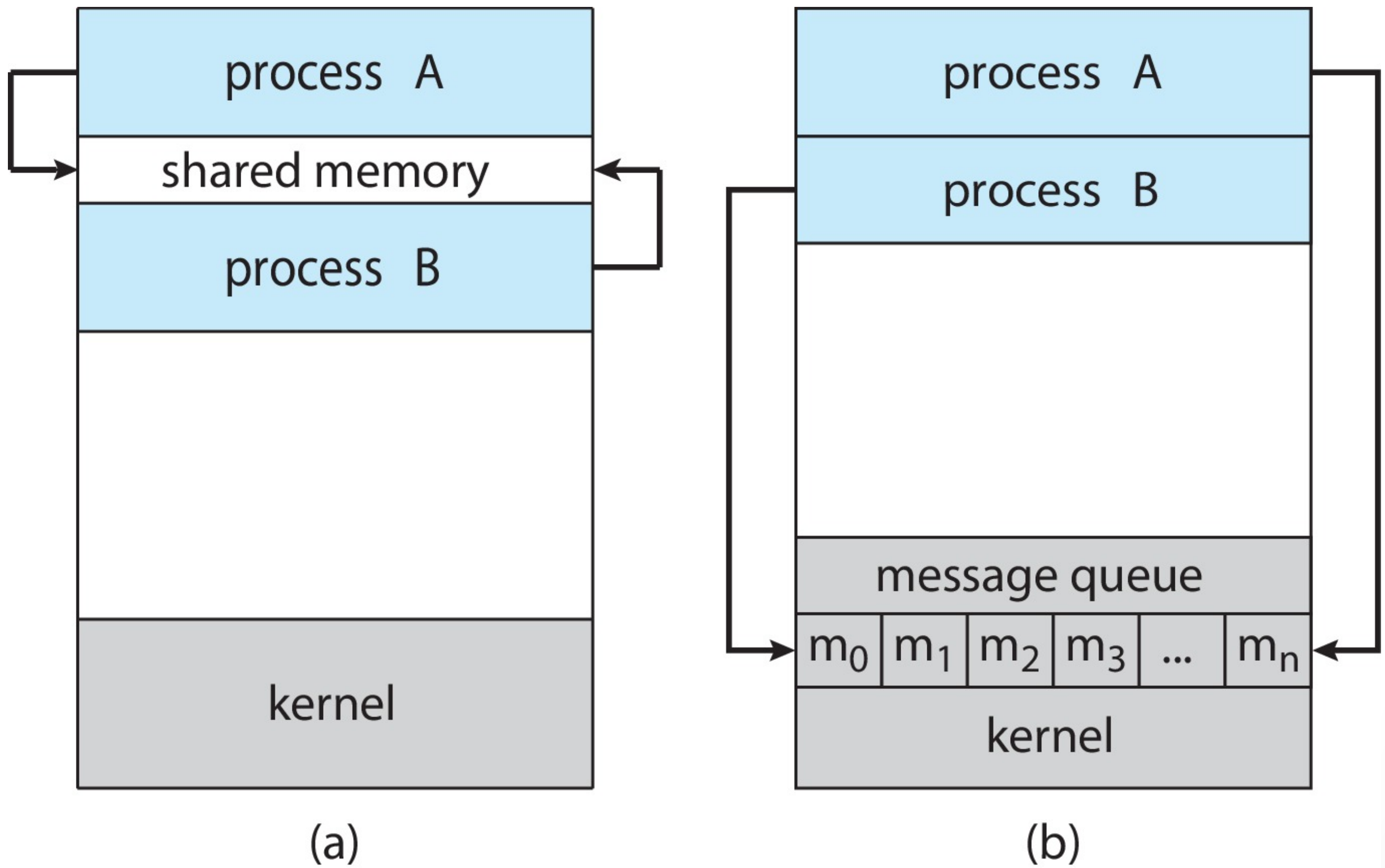
INTERPROCESS COMMUNICATION

Interprocess Communication

- Processes within a system may be ***independent*** or ***cooperating***
- Cooperating process can affect or be affected by other processes, including sharing data
- Reasons for cooperating processes:
  - Information sharing
  - Computation speedup
  - Modularity
  - Convenience
- Cooperating processes need **interprocess communication** (**IPC**)
- Two models of IPC
  - **Shared memory**
  - **Message passing**

Communications Models

(a) Shared memory. (b) Message passing.



Cooperating Processes

- ***Independent*** process cannot affect or be affected by the execution of another process
- ***Cooperating*** process can affect or be affected by the execution of another process
- Advantages of process cooperation
  - Information sharing
  - Computation speed-up
  - Modularity
  - Convenience

Bounded-Buffer – Shared-Memory Solution

- Shared data

```
#define BUFFER_SIZE 10
typedef struct {
  . . .
} item;

item buffer[BUFFER_SIZE];
int in = 0;
int out = 0;
```

- Solution is correct, but can only use **BUFFER_SIZE-1** elements

Producer Process – Shared Memory

```
item next_produced;

while (true) {
  /* produce an item in next produced */
  while (((in + 1) % BUFFER_SIZE) == out)
       ; /* do nothing */
  buffer[in] = next_produced;
  in = (in + 1) % BUFFER_SIZE;
}
```

Consumer Process – Shared Memory

```
item next_consumed;

while (true) {
        while (in == out)
                ; /* do nothing */
        next_consumed = buffer[out];
        out = (out + 1) % BUFFER_SIZE;

        /* consume the item in next consumed */
}
```

Interprocess Communication – Message Passing

- Mechanism for processes to communicate and to synchronize their actions
- Message system – processes communicate with each other without resorting to shared variables
- IPC facility provides two operations:
  - **`send`**(*message*)
  - **`receive`**(*message*)
- The *message* size is either fixed or variable

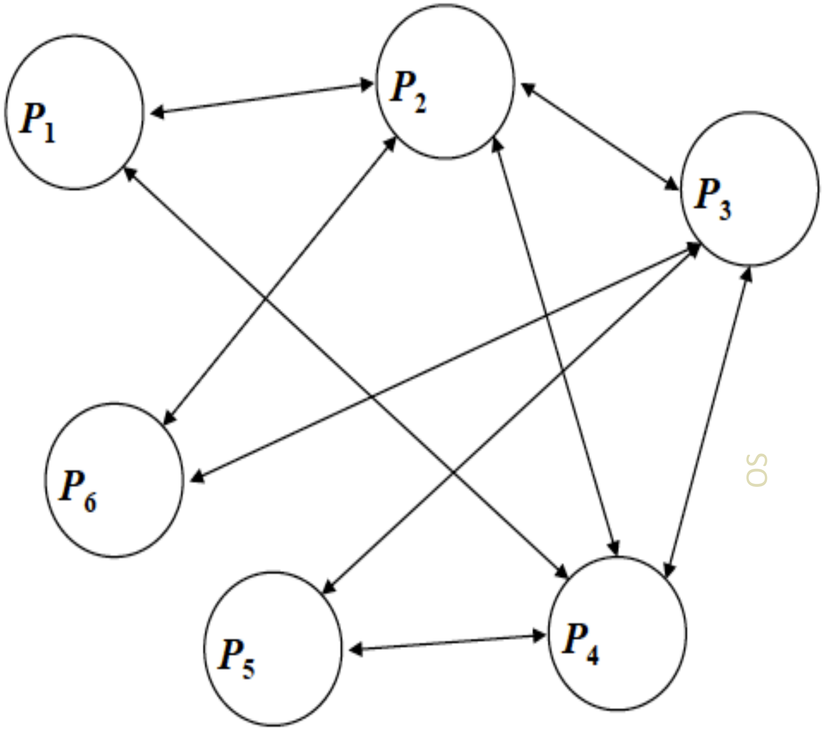
Message Passing (Cont.)

- If processes *P* and *Q* wish to communicate, they need to:
  - Establish a ***communication link*** between them
  - Exchange messages via send/receive

- Implementation of communication link
  - Physical:
    - Shared memory
    - Hardware bus
    - Network
  - Logical:
    - Direct or indirect
    - Synchronous or asynchronous
    - Automatic or explicit buffering

Direct Communication

- Processes must name each other explicitly:
  - **`send`** (*P, message*) – send a message to process P
  - **`receive`**(*Q, message*) – receive a message from process Q
- Properties of communication link
  - Links are established automatically
  - A link is associated with exactly one pair of communicating processes
  - Between each pair there exists exactly one link
  - The link may be unidirectional, but is usually bi-directional



Indirect Communication

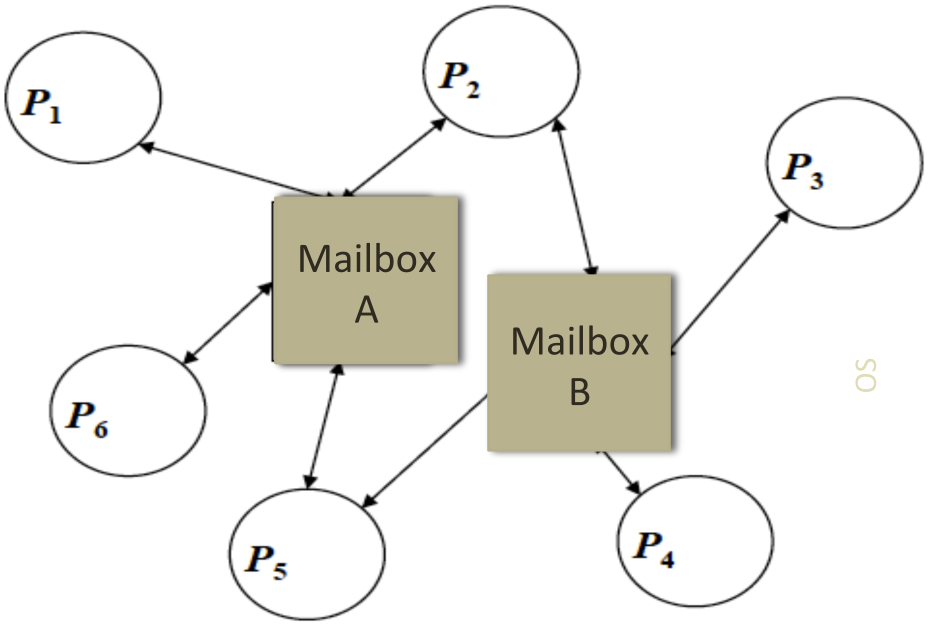
- Messages are directed and received from mailboxes (also referred to as ports)
  - Each mailbox has a unique id
  - Processes can communicate only if they share a mailbox
- Properties of communication link
  - Link established only if processes share a common mailbox
  - A link may be associated with many processes
  - Each pair of processes may share several communication links
  - Link may be unidirectional or bi-directional

Indirect Communication

- Operations
  - create a new mailbox (port)
  - send and receive messages through mailbox
  - destroy a mailbox
- Primitives are defined as:

  send(*A, message*) – send a message to mailbox A

  receive(*A, message*) – receive a message from mailbox A



Synchronization

- Message passing may be either blocking or non-blocking
- **Blocking** is considered **synchronous**
  - **Blocking send** -- the sender is blocked until the message is received
  - **Blocking receive** -- the receiver is blocked until a message is available
- **Non-blocking** is considered **asynchronous**
  - **Non-blocking send** -- the sender sends the message and continue
  - **Non-blocking receive** -- the receiver receives:
    - A valid message, or
    - Null message
- Different combinations possible
  - If both send and receive are blocking, we have a **rendezvous**

Producer – Shared Memory

```
message next_produced;

while (true) {
   /* produce an item in next_produced */

       send(next_produced);
}
```

Consumer– Shared Memory

```
message next_consumed;

while (true) {
   receive(next_consumed)

   /* consume the item in next_consumed */
 }
```

Buffering

- Queue of messages attached to the link.
- Implemented in one of three ways
  1. Zero capacity – no messages are queued on a link.
     Sender must wait for receiver (rendezvous)
  2. Bounded capacity – finite length of *n* messages
     Sender must wait if link full
  3. Unbounded capacity – infinite length
     Sender never waits

Homework

Abraham Silberschatz, Peter Baer Galvin, Greg Gagne, Operating System Concepts, 9th edition, 2013

- Compulsory:
  - Problem 3.2, 3.10: Run a program to illustrate the answer
  - Project 1 and 2 of Chapter 3

Thank you!
Q&A